Coordinating the specification process of research network information systems

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Published in:
Proceedings of the Information Systems Group, The Association of Management AOM

Publication date:
1996

COORDINATING THE SPECIFICATION PROCESS OF INFORMATION SYSTEMS FOR RESEARCH NETWORKS: METHODOLOGICAL DESIGN PRINCIPLES[1]

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ABSTRACT

The rationale for a specification method for research network information systems (RENISYS) is discussed. Some methodological foundations are formulated, resulting in a number of design principles. These state that the specification method must be user-driven, context-sensitive, discoursive, formal, and dynamic. The principles are used to analyze several related types of methods: traditional workflow modelling methods, speech-act based workflow modelling methods, norm-oriented methods, and neo-humanist methods. Actor-centered, context-constrained process composition is presented as the core specification approach to be used in RENISYS.

INTRODUCTION

The scientific research process is rapidly changing from a relatively solitary operation into a much more collaborative effort (Shade, 1994). Research networks, which focus on facilitating the research process, play an important role in this transformation by acting as catalysts of cooperation. These networks can have many roles: coordinating the production of scientific reports, disseminating scientific knowledge to the public, offering advice in societal conflicts, evaluating scientific publications , and so on. Furthermore, research networks are often international, interdisciplinary, and interactive in nature, which only increases their complexity (De Moor, 1994).

A research network can be considered a professional network: a human network which supports its members in accomplishing individual and shared professional goals. This goal-orientedness is one of the crucial distinguishing characteristics of professional networks. Most of the current research networks are still in a rather informal, individual-supporting stage. However, the more interesting roles research networks can play are those aimed at furthering shared group goals. This demands that the network fosters strong collaboration, which can be defined as collaboration in which a group synergistically develops and improves a structured artifact more efficiently than possible by the same group of people working independently (Johnson and Moore, 1994). Thus, two key issues can be identified in research networks, namely their goal-orientedness and the interrelationships between work processes. To accomplish goals via such interrelated work processes, coordination, in other words the management of dependencies among processes (Malone and Crowston, 1994), is essential. This coordination is difficult to achieve, because of the highly distributed and unstructured way of working prevailing in research networks.

Information technology can play a crucial role in improving the operations and impact of research networks. A lot of research has already been done on how to apply information technologies directly relevant to supporting human networking, such as interoperable databases (Brodie, 1992), computerized conferencing systems (Swanson, 1993), mailing lists and of course the World Wide Web. These technologies help network

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[1]Published in: Proceedings of the 14th International Association of Management / Association of Management Conference, Toronto, August 2-6, 1996, pp.95-103.
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participants to create, collect, process, and communicate relevant information much more efficiently. However, to be more useful, the technology should not only offer some technical facilities for individual or ad hoc group use, but also actively support and coordinate strong collaboration.

To facilitate and coordinate their activities, most research networks use a wide array of generic information tools, which often do not meet the actual information needs of their users. Many of these tools have in common that they are technical means that only facilitate single, abstract information and communication processes. The result is that users have to master a large number of unrelated tools and applications before they can reach at least a minimum level of productivity. Furthermore, these tools are not well connected, so that it is not clear how they can cooperate to provide user communities with a seamless research information environment, and help them to coordinate their activities. The issue is that offering a number of loose tools that are not tailored to the specific requirements of the users will not do to satisfy the many information needs of a research network. Instead, integrated and customized network information systems are needed. Such systems combine and configure various tools in line with the ever changing information needs and technologies, so that the provided functionality follows the requirements, rather than the other way around. A network information system is therefore defined as the set of meaningfully combined and configured information and communication processes necessary to support and coordinate the activities of the network participants in their various roles. In order to construct such systems, not only need the dependencies between operational work processes to be analyzed, but there must also be explicit attention for the coordination of the system development process itself.

THE CONCEPTUAL FOUNDATIONS OF THE METHOD

With current approaches to research network information system development, adequate systems are difficult for network participants to create and maintain. Most documentation on how to construct such systems limits itself either to technical tool installation guides, or to - from an information scientific point of view - rather vague topics like the building of a research community (Agre, 1994), and organizational and management issues (BDN, 1992, Pimienta, 1993).

To develop more adequate research network information systems, a more methodological approach is required. In a research network environment the requirements and constituting tools are in a continuous state of flux. We therefore advocate a strong separation between the conceptual specification and technical implementation of the information system. As the major problem is not the technical implementation, but much more the determination of the conceptual dependencies between functionality components and their determinants, we only address the specification aspects of the development process.

The research question now becomes: what are the characteristics of the specification process of research network information systems? How should this process be structured to arrive at the best possible specifications? These questions are being addressed in the RENISYS (Research Network Information System Specification) project. Its main objective is the development of an operational specification method. In this paper, the research approach used for the development of this method will be outlined.

To develop a method which has a sound theoretical basis, is conceptually clear and technically implementable, three main concepts, namely research networks, information system, and specification method design principles, need to be studied in greater detail. This will help to focus the research problem, and to make better founded design decisions.

The Research Network

First, the community in which the network information system is to operate needs to be known. A research network is seen as a special case of a professional network. One research network characteristic is the complexity and dynamics of its scope, organization, and technological support. Many participants are involved in numerous highly interrelated and evolving tasks, using a large number of information technologies. Another important feature is that the operations and evolution of these networks take place in a highly distributed way. To a large extent, new initiatives are started and developed in a bottom up, unplanned, and uncoordinated fashion by the participants themselves. They are often unaware of other relevant initiatives going on, and can have widely different ideas about what needs to be done and in what order. A final issue is that there is very little or no functional hierarchy; who has the authority to make the decisions is thus not very clear by default. This all means that coordination of the network processes, and thus the modelling of the derived system specifications, is hard to achieve using traditional means.

The Network Information System

Because of our process focus, we are especially interested in one particular kind of groupware, namely workflow management systems. These are systems that allow for the design, execution and management of business processes and activities in a network (Abbott and Sarin, 1994). The kind of system that is most appropriate in the research network context is that of the ad hoc workflow system. Most workflow systems are transaction-focused, which means that they create structures to implement and enforce frequently recurring processes. Ad hoc applications, on the other hand, focus more on supporting creative knowledge activities. Their main aim is to provide some sort of control to make sure that tasks, responsibilities, etc. are delivered (Khoshafian and Buckiewicz, 1995). We postulate that both these deliverables and the control structures are of a much higher complexity and fluidity than in transaction-focused systems, making their specifications even harder to generate. Instead of making very deterministic workflow process models, the specifications of this kind of systems should therefore first of all comprise the various kinds of work flow process *conditions* , their triggers, and effects in terms of responsibilities and obligations.

Fundamental Specification Method Design Principles

A considerable amount of work has already been done on the construction of groupware and workflow management systems. Existing systems provide many facilities for managing and executing already established work processes. However, the preceding process of how the design of these work processes itself is to be managed, more specifically in the case when the designers are the users themselves, is still very much uncharted territory. This is where the RENISYS specification method should play an important role.

In order to deliver useful specifications of ad hoc workflow management systems for the research community, RENISYS has to incorporate five major design principles, partially described in (De Moor, 1995). The method must be user-driven, context-sensitive, discoursive, formal, and dynamic.

• *A User-Driven Method*

The basic design principle is that the method must be user-driven, which means that it allows users to define their own information needs themselves, as well as the solutions in terms of (partial) workflows. In research networks, resources are often lacking to provide for professional information system development assistance. An even more fundamental problem is that needs analysis done by an information systems expert does not do justice to the high degree of changeability and conceptual richness of the research network collaborative activities. A user-driven approach allows for a much higher degree of system customizability. For system specification this means that it must be closely linked to system use. Whenever users feel constrained by their current palette of available actions, they should be able to adapt and extend them. The method should guide them in this by making sure that such modification takes place adhering to the overall network norms.

• *A Context-Sensitive Method*

The method must also be context-sensitive. This entails that the method allows for the easy detection and representation of relevant changes occurring in the world in which the information system is used, and takes appropriate subsequent specification actions. Often, users' information needs are expressed directly in terms of functional actions, such as `copy file' or `send mail', at the technical information and communication process level. However, what one is really interested in during the specification stage is `effective functionality': that part of the total technical functionality that is actually accessible and useful to the user (Goodwin, 1987). This means that it is essential that one knows about what determinants drive the use of the information system, and therefore a much deeper and richer user world model is necessary. A context-sensitive method now allows for the representation of information requirements in terms of natural user domain concepts, and helps to translate them into configurations of (high-level) technical functionality components.

• *A Discoursive Method*

A fundamental issue has not yet been described: the source of the dynamics in research network operations and development. Of course, a change in process state or definition can automatically trigger a whole series of other process state changes. Still, the ultimate source of this change is a human actor. However, these actors do not initiate change in complete isolation. Characteristic of professional networks is that the participants collaborate, not only on their substantive actions, but also on the system specification. Therefore, each proposed change must be communicated to actors affected by that change, be modifiable by those actors and finally approved, before these changes are committed.

This requires a discoursive view on the information system specification process. In such a view, various properties of the communication context, such as clarity, truthfulness, correctness and appropriateness, are explicitly examined through discourse. A major problem, however, is that the discoursive processes that are so fundamental in network information system specification are often not created spontaneously (Lyytinen and Hirschheim, 1988). Thus, a discoursive method must not only assist in the modelling of specifications, but also actively initiate, facilitate and guide the human discoursive process of coming to acceptable process specifications.

• *A Formal Method*

The method needs to be formal. Such a method allows for the unambiguous description of network semantics and for (semi)automatic reasoning about the properties of the system, so that the completeness and consistency of the specifications can be guaranteed. Many specification methods are of an informal kind: information system concepts are only vaguely described, the various specification steps can often be interpreted in many different ways, and the system integrity of the different aspect models and their connections is not ensured. These problems can be addressed by using a formal method, preferably based on some kind of mathematical specification language. One can now enjoy the advantages of early discovery of errors, precise documentation, and a precise control over the development process (Lano and Haughton, 1991), more particularly the specification process.

• *A Dynamic Method*

The method must be dynamic in the sense that it allows specifications to be produced incrementally. Many specification methods, such as those originating from the waterfall paradigm, are based on the traditional information system life cycle view and aim at producing relatively stable, if not rigid information systems. They create specifications in subsequent steps and have a well-defined stage of delivery. Typically, the specification steps are carried out at once on all (intermediate) specification data, which have been defined from a unified perspective. However, due to the extremely dynamic nature of research networks, and because there is little support for recycling components and steps, it is difficult to keep system specifications up to date using such traditional methods.

Thus, a dynamic method is required that can produce an evolutionary system, which means that the method allows the information system to be relatively easily adapted to changes in its environment. An evolutionary or dynamic strategy is the only feasibly way for the development of highly unstructured and unstable systems. It allows each end-user to relatively easily contribute a small piece of the system requirements at a time, without duplicating or contradicting the contributions of others (Orman, 1989). This is essential in research networks, where contributors often work on their own, are at any particular moment in time involved in different stages of the specification process, and often cannot commit themselves to prolonged specification efforts.

APPLYING THE DESIGN PRINCIPLES TO RELATED METHODS

Before we can determine the niche for RENISYS to fill, it is necessary to first examine the strengths and weaknesses of some related classes of methods. They have been selected for their possible specific contribution to the operationalization of one or more design principles. Space permits no exhaustive analysis; therefore only one illustrative example will briefly be discussed for each method class.

• *Traditional Workflow Modelling Methods*

These methods are strongly process-oriented. They allow for the precise description of typical process dependencies, such as sequences, repetition, and parallelism. A good example is the ExSpect method (Van der Aalst et al., 1995). In ExSpect, complex tokens can be moved between input and output channels and stores via transitions. The method has especially proven useful for the modeling, simulation, and analysis of the logistical workflows of business organizations.

ExSpect provides a good formal and dynamic approach to network specification. However, user-drivenness, context-sensitivity, and discoursive features are not incorporated.

• *Speech-Act Based Workflow Modelling Methods*

These methods are based on the language action approach, in which organizations are interpreted as patterns of linguistic actions by which people coordinate and structure their work with others (Kensing and Winograd, 1991). Speech-act based methods are much less deterministic than traditional workflow approaches. They allow the system users to precisely define and link their communication patterns, and thus clearly determine the responsibilities for the processes that need to be carried out, and the obligations that they entail. These methods are thus especially suitable for ad hoc workflow-like modelling purposes, as vigorously defended in Winograd (1994). Typical examples are the Action Workflow Approach (Medina-Mora et al., 1993) and the DEMO (Dynamic Essential Modelling of Organizations) specification method (Dietz, 1994). In DEMO, the core concept is the transaction, in which actors in a so-called actagenic conversation agree on an essential action to be carried out. The actors agree that this action has been satisfactorily performed by producing a fact in a factagenic conversation.

Many of the same comments made on the usefulness of traditional workflow modelling methods apply to DEMO. Context-sensitivity is somewhat higher, in that transactions are more natural concepts than process transitions. However, there is still a large gap between the conceptual domains of research network participants and the generic transaction concept. Information system solutions cannot be derived from these high-level concepts without going through complex additional analysis steps. Furthermore, the ultimate objective of these analysis steps is not so much to guide the modelling process of functionality components such as information tools (as is the goal of RENISYS), but only the division of responsibilities for conversing about and carrying out operational tasks. Other shortcomings, from our particular perspective, are that speech-act based methods still are not user-driven and do not answer the important question of how they must initiate, facilitate, and guide the discoursive specification process. However, the well-developed conversation formalisms can be used as primitives in the modelling of the specification discourse of our method.

• *Norm-Oriented Methods*

Norms serve as important instruments to guide people in the way they are allowed to define and carry out processes. They help to define what are the desired, permitted, or forbidden courses of action, including specification processes. Important theoretical contributions to the formalization of the norm concept have been made by deontic logic, which can be used to reason about properties of normative social systems (Meyer and Wieringa, 1993). However, only little attention has been paid to norms in current specification methods. One of the few exceptions is MEASUR, a norm-oriented semiotic approach to information system specification (Stamper, 1993). The most fundamental concepts of the theory are affordances and norms. An affordance is a universal invariant which constitutes the repertoire of an agent's behaviour. A norm is a social affordance which has been accepted by a community as common ground. Information system specification now proceeds as follows. First, the basic entities in the physical and social world are described in an ontological chart. Then, this chart is used to do a semantic analysis, in which the norms that govern the behaviour of the agents are described.

MEASUR is strong in its characteristics of formality and especially dynamics, as old concepts are never discarded, and new concepts can easily be added to for instance an ontological chart. It is also considerably context-sensitive, in that high-level concepts and their interrelationships can easily be represented in the ontological chart, without users being forced to express themselves in a straitjacket of abstract modelling concepts. Still, the proper translations of these free specifications into relevant clusters of information system functionality components is hard to determine. Furthermore, MEASUR claims to be user-driven. This claim cannot completely be supported, however, as it is hard to see how users can initiate their own specification processes and develop workflow solutions without the help of a professional well-versed in the various components of the method. The method is not discoursive.

• *Neo-Humanist Methods*

Neo-humanism is a philosophical school which concerns itself with the establishment of the conditions for human existence that facilitate the realization of human needs and potentials (Hirschheim and Klein, 1994). Important concepts are social constructs as emancipation and participation, which also play a key role in creative, independent communities like research networks. Starting from this approach, neo-humanist methods thus heavily stress the viewing of information systems development as a social process. One exponent of this approach is ETHICS, which is analyzed by Hirschheim and Klein, 1994. Its goal is to promote participatory socio-technical information system design. The method guides subjects through such stages as essential systems analysis, various sorts of solution generation and ranking, and detailed work design.

The strength of ETHICS is in its user-drivenness, context-sensitivity, and, to some extent, discoursive characteristics. In a step-by-step approach, users control and are guided in their usage context analysis efforts. However, the weakness of the method is in the lack of formality and dynamics. Completeness and consistency of the specifications cannot be guaranteed, and the analysis takes place in a typical waterfall, non-incremental fashion.

RENISYS: SPECIFICATION THROUGH PROCESS COMPOSITION

We now know the general design criteria RENISYS will have to satisfy. However, we also need a concrete methodological approach. For this, we build on the emerging work on 'process composition'.

During network information system use, there is often a need for radically tailoring the system, meaning that very large changes can be made to the system functionality , without users having to leave their usage domain (Malone et al., 1995). This means that process composition is necessary: users must be able to modify their own process space. Both the environment in which the work processes take place needs to be modelled and support must be given for participants to compose their own paths within such a space dynamically (Fitzpatrick and Welsh, 1995). However, in what way these specification goals should be realized has not yet been studied in much detail. One main criticism of current approaches to process composition, such as described in (Fitzpatrick and Welsh, 1995) could be the lack of formality of representation and especially the lack of support for the dynamical group processes in which the overall process space is to be modified. It is this white spot on the map that RENISYS will aim to fill in, while adhering to the mentioned design principles.

One core concept in our approach to process composition is that of the network information system context. This is defined as the complete set of determinants of change of an information system which can be activated during its use. It consists of a reference framework, various ontologies, and norm and state knowledge bases. The reference framework is used to organize usage context elements, as defined by the participants. Mapping processes determine how these elements can be linked and transformed into information system functionality terms, understandable by the system implementors. An early version of the framework was described in more detail in (De Moor and Van der Rijst, 1995). The reference framework is filled with various categories of ontologies. These ontologies, defined as specifications of conceptualizations (Gruber, 1993), in turn allow for the efficient definition, storage, and retrieval of different kinds of norm and state knowledge.

During the use of the method, this knowledge representation framework is continuously being (re)defined by the users. When tailoring system functionality, many methods only distinguish a monolithic kind of user, representing a person or subject in the real world. In RENISYS, however, users involved in process composition can play a large number of actor roles. An actor is an abstract subject to which a set of meaningfully (as determined by the network participants) related processes is attached. Besides being allowed to have commitments and responsibilities, each actor also has an action space (simplified: that part of the total network functionality controlled by the actor), and a process composition space (the total set of potential process configurations and combinations an actor is allowed to make). Thus, the actor concept provides us with a major structuring mechanism not only for task coordination but also for specification generation through process composition.

CONCLUSIONS AND FUTURE WORK

The goal of the RENISYS research project is to construct a specification method for research network information systems that concentrates on supporting the complex dynamics of the processes in which participants of a professional community generate their own high-level information system specifications. This paper touched upon some of the most important design principles to be taken into account in the development of the method. To determine its position in the methodological landscape, some related specification methods were charted by applying the defined principles.

A conceptual basis for the method has been established in already conducted research. An initial, broad literature review was conducted in (De Moor, 1995). The role of the reference framework in assisting in the specification process, and the relation with the related Dynamic Essential Modelling of Organizations (DEMO) specification method were studied in (De Moor and Van der Rijst, 1995) and (Van der Rijst and De Moor, 1996). The need for RENISYS, the context in which the method is to be used, as well as a broad research agenda are discussed in (De Moor, forthcoming). Current efforts are focused on the development of a generic user-accessible ontology and norm definition mechanism, based on the theory of conceptual graphs. Work has also started on the development of a RENISYS implementation. This concerns a client-server based tool, wherein the server functionality is constructed using the highly portable TCL (Tool Command Language) and the clients will be ordinary HTML browsers, guaranteeing a wide user base and good opportunities for obtaining experimental data.

A main focus of our future research will be on the relationships between the information system context and the actor process spaces (actor and process composition spaces). When the context (ontology, norms or state) changes, what does this mean for the spaces of the various actors? In turn, how does a space change affect the overall context? What happens when actor process spaces are mapped to subjects (one subject can control more than one actor process space, one process space can be controlled by more than one subject)?

One of the major remaining issues to be researched is the conceptualization and formalization of the required process composition discourse support. Questions to be answered are: how are the discoursive processes influenced by the network information system context? How do they change the context itself? What exact role do discoursive processes play in the specification process? To answer this last question, social philosophy, such as Habermas' theory of communicative action[3], and the interpretation of social action theory by Hirschheim et al. (1991) are certainly relevant, as they focus on the importance of user-control over communication and the

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[3]For an in-depth treatment of Habermas' main ideas, see McCarthy (1978)

information system development process. Also, discourse protocols such as SANP (Speech-Act Based Negotiation Protocol) (Chang and Woo, 1994) may provide leads to help define concrete process composition and conflict management mechanisms.

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